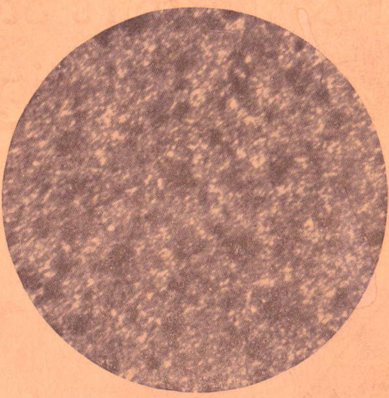
Mr. D. Portway

THE

Tool Hardeners' Handbook on Steel



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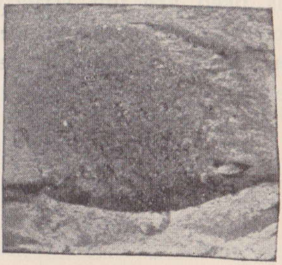
THE

TOOL HARDENERS' HANDBOOK ON STEEL



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NOTE.

This book is written for the practical man ; some of the statements made and expressions used are not strictly scientifically accurate, but are believed to be in the best form to help the reader to get the best results.

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ILLUSTRATIONS

PART I.

Hardening Shop Equipment

Hardening Shop Equipment.

Which is the best Furnace for heating Tools ?

The above is a question which is often asked, and which is difficult to answer in a general way. Much depends on the size and shape of the tools to be treated, and also the output required.

Generally speaking we recommend salt bath furnaces for small tools, and modern coal-fired furnaces for large articles.

(The design of heat treatment furnaces has improved very much recently, and there are now several firms who have specialised in this work.)

Advice will gladly be given by the authors, who have a large experience—and are not interested in any company selling hardening plant.

The Smiths' Hearth.

The Smiths' Hearth is the most common and the worst type of hardening fire. Its use should absolutely be confined to odd jobs. It is difficult to heat tools evenly in it, and no pyrometer can be used.

Before commencing, clean out the clinker, pile the coke up and turn on the blast so as to get a large volume of red-hot fuel. The larger the mass of hot fuel the better your chance of getting the tool evenly heated. Turn off the blast, place the tool in the middle of the red-hot coke, pile the coke well over it and *use the blast as little as possible.*

When hardening high-speed steel dip the tool, when a good red, in a tray of common table salt, which melts and forms a protecting covering, lessening the risk of decarburisation.

Lead Baths.

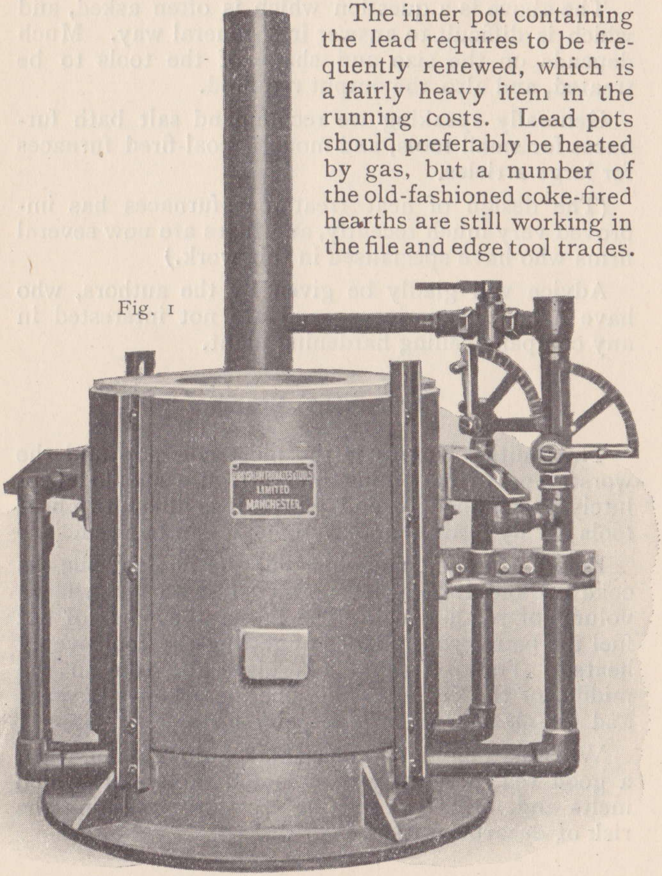
Lead Baths are largely used for hardening files, chisels, reamers, etc.

As lead is heavier than steel, steel articles have to be pushed down into and held under the lead.

A cowl and light stack must be provided, as the lead fumes are unpleasant to the worker.

The inner pot containing the lead requires to be frequently renewed, which is a fairly heavy item in the running costs. Lead pots should preferably be heated by gas, but a number of the old-fashioned coke-fired hearths are still working in the file and edge tool trades.

Fig. 1



Lead pots may also be used for tempering (see also p. 23).

Fig. No. 1 shows a typical modern lead bath.

Most lead pots should not be used for higher temperatures than 900°C. The melting point of lead is 327°C.

The illustration is taken from the catalogue of Messrs. Brayshaw Furnaces & Tools Ltd., Mulberry Street, Hulme, Manchester. Similar apparatus is also sold by Messrs. Fletcher, Russell & Co. Ltd., Warrington; The Richmond Gas Stove & Meter Co. Ltd., Warrington, and The Davis Gas Stove Co. Ltd., Luton.

Salt Bath Furnaces.

Salt Bath Furnaces differ from lead baths in that there are no fumes, steel articles will not float in them and consequently a tray can be used, and the salt sticks to them on removal from the bath.

They have several very great advantages :—

(*a*) Salts can be obtained to freeze (and melt) at any temperature. Great use can be made of this to get correct hardening temperatures without the expense, etc., of pyrometers. *E.g.* for an ordinary carbon tool steel ·90 carbon or over of which the hardening temperature is (for practical purposes) 750°C., use a salt which melts at 750°C. Keep this just over the melting point, When the tool is removed from the bath quench it directly the salt freezes on it.

(*b*) Salts can be obtained for both higher and lower temperatures than lead. The temperature range is very wide. High-speed Steel may be hardened in a salt bath.

(*c*) Steel tools may be hardened in the **bright** state without forming scale, etc.

(*d*) Special salt baths can be used for quenching to avoid distortion.

Fig. 2 shows a typical salt bath. Made by Messrs. Brayshaw Furnaces & Tools Ltd., Manchester. Similar plant is catalogued by Messrs. Fletcher, Russell & Co. Ltd., Warrington, The Richmond Gas Stove & Meter Co. Ltd., Warrington, The Davis Furnace Co., Luton, and Messrs. H. Fuller & Co. Ltd., Broadfield Works, Sheffield (who specialise in special salt baths for hardening high-speed steel.)

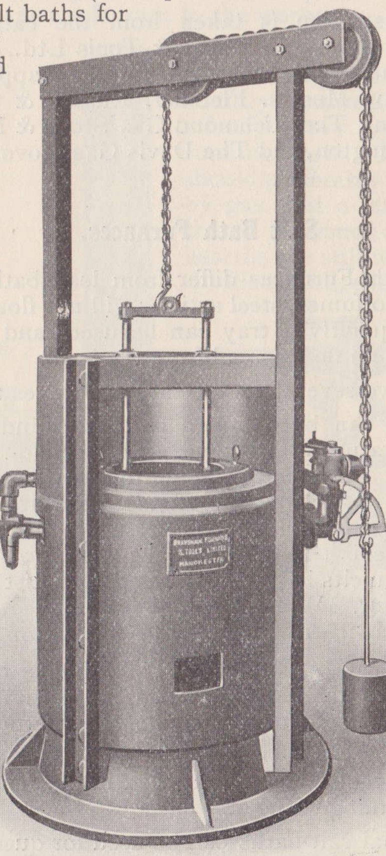


Fig. 2

Gas Fires for High-speed Steel.

Fig. 3 shows the now largely-used double chamber Gas Fired Furnace for high-speed steel. The tools are first placed in the top chamber for pre-heating to a good red heat, and then rapidly brought up to the hardening temperature in the bottom chamber.

The illustration is from the catalogue of Messrs. Brayshaw Furnaces & Tools Ltd., Mulberry Street, Manchester. Similar furnaces are also made by Messrs. Alldays & Onions Ltd., Birmingham, The Richmond Gas Stove & Meter Co. Ltd., Warrington, The Davis Furnace Co. Ltd., Luton, Messrs. Fletcher Russell & Co. Ltd., Warrington, etc.

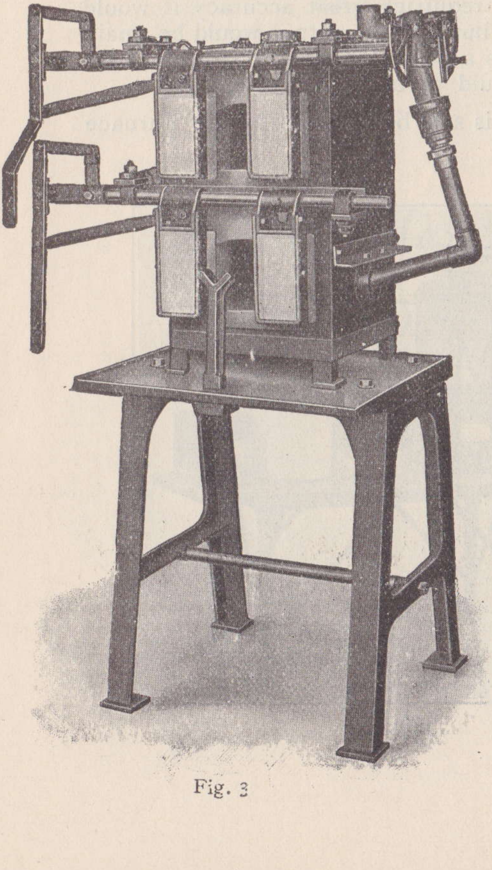


Fig. 3

Wild Barfield Electric Furnace.

Fig. 4 shows the Wild Barfield Electric Furnace which is being largely advertised, and which is a special salt bath electrically heated. The principle on which this apparatus works is that the temperatures at which ordinary tool steels (·90%c. and over) become non-magnetic and their hardening temperatures are the same.

We have no personal experience of this furnace, but would be inclined to think that for small articles and special work requiring great accuracy it would give good results, but that the output would be small. For larger outputs a good salt bath apparatus of the ordinary type would probably be better.

The equipment is sold by Augusts Muffle Furnace Ltd. Halifax.

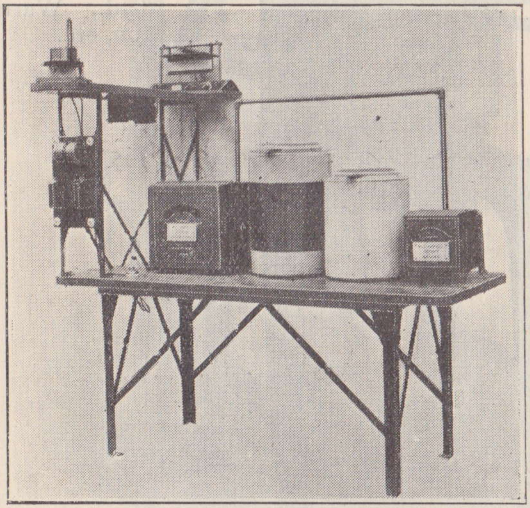
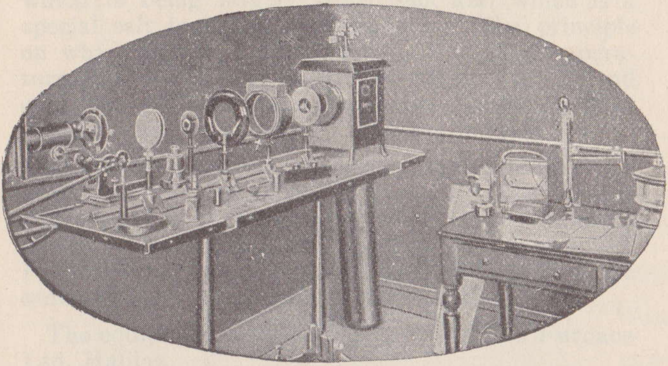


Fig. 4

PART II.

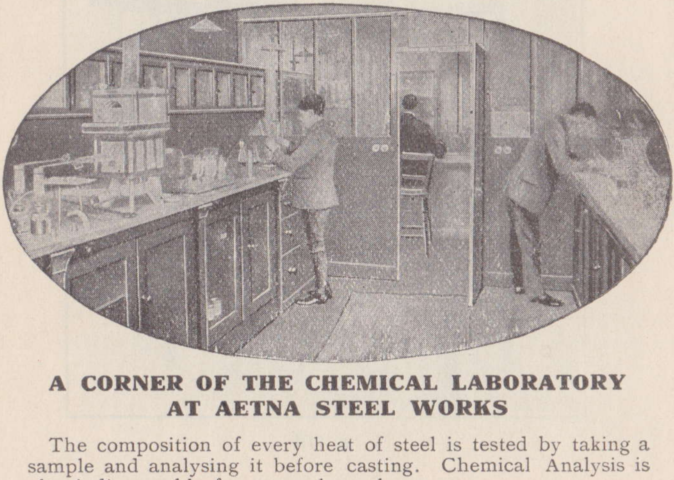
Forging, Hardening, Tempering, etc.

Steel Works Laboratory Apparatus



APPARATUS FOR TAKING MICROPHOTOS OF STEEL.

The Microscope is chiefly used for research work on the effects of heat treatment.



A CORNER OF THE CHEMICAL LABORATORY AT AETNA STEEL WORKS

The composition of every heat of steel is tested by taking a sample and analysing it before casting. Chemical Analysis is also indispensable for research work.

Table of Forging and Hardening Temperatures for Tool Steel.

	Forging* Highest	Forging* Lowest	Hardening	Quench in
	°C	°C	°C	
Carbon Tool Steels, up to ·90% c. ...	900	700	800	†
do. do. over ·90% c. ...	850	700	750	†
High Speed Steel (all grades) ...	1000	880	1250	Oil or Air
S.H.1.	1000	800	950	Oil or Air
Finifast	900	750	825	Water
Spearos.—Very Mild and Mild ...	950	800	850	Oil
,, Medium	925	800	825	Oil
,, Full, Hard, & Very Hard	900	800	800	Oil
Jacksos and 2Z, to ·90% c.	900	725	775	Water
,, ,, over ·90% c. ...	875	725	750	Water
S.A.J.	850	700	800	Water
Shrinkos...	900	725	800	Water
Nonshrinko	850	725	750	Oil
Easietreat	900	700	800	Oil or Water

* The steel must not heated above the "highest" temp., forging must not be continued below the "lowest" temperature.

† Oil or Water, depends for which Steel is made.

Notes on Heating Steel.

Judging Temperatures.

Practically the whole art in obtaining good results from tool steel lies in heating them correctly, and except where proper furnaces and pyrometers are available, in the judgment of temperatures by eye.

Unfortunately, the exact appearance or "colour" of heated steel which corresponds to a certain temperature is exceedingly difficult to describe.

An accepted colour-temperature chart and also our improved version of same are shown below, but such expressions as "Cherry Red," "Bright Cherry Red," "Red," &c., convey very little to the ordinary man, and the colours are very difficult to reproduce chromatically correct. Such charts are, at best, a very rough guide.

By aid, however, of a simple well-known method (see pp. 21, 22) it is possible with a very little practice to get a fair idea of the correct hardening temperature, and from this, with the help of the colour chart and tables, of forging and annealing temperatures also.

Taylor and White's Colour and Temperature Table.

	Fahr.	Cent.
Black Red	990°	533°
Dark Blood Red	1050°	565°
Dark Cherry Red	1175°	634°
Medium Cherry Red	1250°	676°
Full Cherry Red	1375°	745°
Light Cherry	1550°	843°
Salmon	1650°	899°
Light Salmon	1725°	940°
Yellow	1825°	995°
Light Yellow	1975°	1078°
White	2220°	1203°

S. & J.'s Improved Colour-Temperature Scale.

	Fahr.	Cent.
Black Red	1112°	600°
Dark Red	1292°	700°
Ink Red	1562°	850°
Light Red	1697°	925°
Orange Yellow	1832°	1000°
Lemon	2102°	1150°
Yellow White	2282°	1250°
Dazzling White*	2372°	1300°

*Hurts most people's eyes.

Special Points re Heating Steel.

Heat gradually and uniformly. Turn the tool constantly in the fire. Sharp edges and corners always tend to heat up more quickly than the mass of the tool; to equalise, withdraw the tool frequently from the fire and hold it for a second or two outside, edges and corners then lose their heat rapidly and cool down to the same temperature as the rest of the tool.

Steel must not be allowed to soak in the fire after it has once attained, **throughout its mass**, the desired temperature. Carbon Steels heat through pretty quickly, but Alloy Steels and High-speed Steels take longer, and the mistake is very common of trying to heat them too rapidly and removing them from the furnace before the centre is properly soaked through, with the result that when forged the centre does not flow as easily as the outsides, and tends to cause cracks. As a rough rule for heating alloy and high-speed steels for forging, one hour must be allowed for each inch of section (*e.g.*, a bar 3″ square would take 3 hours); a very large percentage of the wasters made in drop forging alloy steels are due to the steel not being heated through. Steel bars, after forging, should be convex at the end (Fig. 1); if concave (Fig. 2), or square (Fig. 3) it shows that the centre has not been properly plastic and undue strains have undoubtedly been set up, even if the steel is not actually cracked.

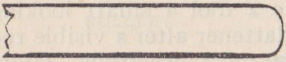


Fig. 1

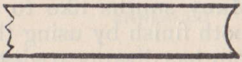


Fig. 2

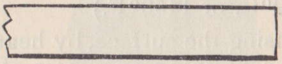


Fig. 3

Decarburisation, &c.,

The carbon on the outer skin of steel which is bright red hot will combine with any oxygen in the surrounding gases, and the surface of the steel is decarburised. Steel should, therefore, always be heated in a reducing atmosphere. A "Reducing" atmosphere is one in which there is **no** excess of oxygen above what is required for complete combustion (as opposed to an "Oxidising" atmosphere). If gas re-heating fires are used the air supply to the burners should be cut down until a luminous white

flame is obtained (a gas blue flame is oxidising). If a smith's hearth is employed, use a clean solid bed of fuel so that the air from the tuyere has to pass through 3 or 4 inches of incandescent fuel before reaching the steel, and use as little blast as possible.

If a muffle is used throw in a spoonful of powdered charcoal (which burns and combines with the oxygen in the air) and keep the door closed.

Notes on Forging.

Heat slowly and uniformly.

The main points to avoid are :—

(1) Overheating which makes the steel brittle. See table on p. 15.

(2) Finishing at too low a temperatue, which also makes the steel brittle and is every bit as important. See table on p. 15.

Many smiths like to give a tool a smart looking smooth finish by using the flattener after a visible red colour has disappeared; this is most disastrous. High-speed Tools must not be finished below a bright cherry heat (790°C. or 1450°F.)

(3) Decarburising the surface, by heating in a flame or atmostphere containing an excess of oxygen, with the result that the steel apparently won't harden or has hard and soft spots (see above).

(4) Don't draw round steel to a smaller size or a taper without first hammering it square: reduce to approximately finished size as square then hammer in the corners and round off, otherwise the bar is liable to split up the centre or crack in hardening.

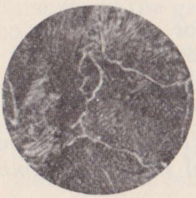
The harder the steel the greater care is required in forging.

If a blacksmith's hearth has to be used keep a thick bed of fuel between the blast and the tool and use as little blast as possible.

Why Steel Hardens, etc.

Steel is crystalline—like sugar.

Crystals however of the same steel when examined under the microscope vary considerably in their size and constitution according to the condition of the steel. The effects of hardening, tempering, annealing, etc., are brought about by alteration of size, form and microconstituents of the crystals.



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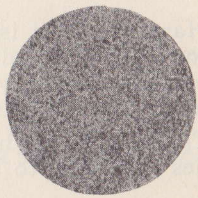
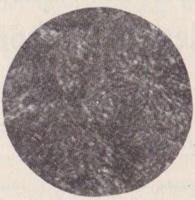


ANNEALED



HARDENED & TEMPERED

Hardening

Just as ice when heated to a certain definite temperature becomes water just so the microconstituents of steel crystals when heated to a fixed temperature (critical point) change and if the steel is quickly cooled or "trapped" in that condition the steel is hardened ; just as the melting point of ice varies somewhat

if it contains foreign substances so the hardening temperature of different steels varies according to their composition, but it is always the same for the same steel.

Unless steel is quenched from above the hardening critical point it will not harden and so long as it is over the critical point *there is no advantage (and there are considerable disadvantages) in heating it hotter.*

If heated considerably above the hardening point steel becomes "burnt" and is spoiled.

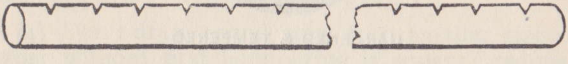
Tempering.

Hardened steel is too brittle for use in that condition; if hardened steel is heated up again, or "tempered," the crystals gradually tend to go back to their original "soft" state.

The loss of hardness and increase in toughness varies according to the amount of tempering given.

How to Learn to Harden Steel correctly.

Take a short piece of the steel required, say, 12″ long × ¼″ to ½″ section, and nick this fairly deeply at intervals of about ½″, as shown :—



Heat this in the fire so that one end is considerably over the correct hardening temper, the heat gradually tapering off to the other end which is much below the correct hardening temperature. Withdraw from the fire, study the hot bar carefully, and note at which notch you consider the temperature is about correct for hardening. Quench the bar and break off the notched pieces one by one.

At the over-heated end the fracture will be very crystalline and "sugary" looking, gradually becoming less so and finer, until a beautifully fine and silvery fracture is obtained, which indicates the correct temperature.

Repeat the experiment until you find you can regularly judge at which notch the correct fracture will occur.

Then repeat again and again, now trying to get the **whole** of the bar the correct temperature : break off the notched pieces, as before, to test whether correct by fineness of the grains.

Constant practice is necessary to keep your hand in, and it is very easy to be deceived according to the way the shop is lighted. For example a bar of steel which shows red in a dark place looks black in bright sunshine. For this reason a fairly dark hardening shop is an advantage.

In High-speed and Self-hardening Steels it is possible to get a perfect looking hardening fracture without heating the steel sufficiently to have "red-hard" properties ; with all other tool steels, however, a perfect fracture is a sure sign of correct hardening. It should also be borne in mind that High-speed Steel which is hard to the file is not necessarily correctly hardened and on the other hand it sometimes appears slightly "soft" to the file when properly hardened.

(For Table of Hardening Temperatures, see page 15.)

General Notes on Hardening.

Heating must be done slowly to avoid excessive and irregular expansion and to ensure that the steel is heated uniformly. If a smith's fire has to be used keep withdrawing the tool from the fire for a few seconds so that the thin edges can cool down to the same temperature as the body of the tool. Uniform heating

is essential otherwise cracks will occur and sharp edges are likely to break off on quenching. The tool must be turned constantly in the fire. Never grip a hot tool with cold or wet tongs. A large proportion of complaints made to steel-makers that steel "won't harden" are due to decarburisation (see p. 18). If this has occurred and is not excessive the decarburised surface may be ground off and the tool rehardened.

Tools which have been overheated can be partly restored by annealing and rehardening at the correct temperature.

Move the tool about in the quenching liquid until nearly cold; articles of large size must be left in for a considerable time.

Some steels are made to harden in oil and some in water: if uncertain, write the steel maker.

Salt bath furnaces for hardening are strongly recommended.

Tempering.

Colour Temperature Scale for Tempering.

Colour	Temperature Cent.	Temperature Fahr.
Light Straw	220° to 230°	440°
Dark Straw	240°	464°
Yellowish-Brown	255°	490°
Reddish-Brown	265°	509°
Purple	275°	529°
Violet	285°	545°
Cornflower-blue	295°	563°
Pale-Blue	310° to 315°	595°
Sea Green (or Grey)	330°	626°

For accurate work oil or lead or salt baths are the most uniform and reliable. Oil can be obtained which can be safely used up to 230°C.

Lead melts at 327°C. but a mixture of lead and tin or lead and antimony (cheaper than tin) melts at lower temperatures as follows :—

Per cent tin	10	20	30	40	50	60
Fluid at ...	300°	275°	255°	230°	210°	185°C.

Per cent Antimony	5	10	13
Fluid at ...	290°	270°	250°C.

The temper colours generally used for various classes of tools are given on pp. 32-34

Annealing.

Always buy tool steel annealed.

Annealing in engineering works is usually in order to soften tools so that they can be machined. The "softest" steel does not always machine the best.

Quick Method.

Reheat to **just below** the hardening point and cool in air. The nearer the critical point, the softer the steel. The danger of this method is that in the attempt to get as near to the critical point as possible this is

Annealing High-speed and Self-hardening Steel.

High-speed (I) heat slowly to 850/900°C. ; maintain temperature till thoroughly soaked through (say 1½ hours to 5 hours according to mass) ; cool slowly.

(II) Odd tools can be softened by a quicker method—heat to 650/700°C., maintain for 30 minutes; cool slowly.

SH1 and SSH See (I) above, but heat to 825/850°C.

N.B.—All the above steels scale freely at annealing temperatures and should be packed in ashes or lime (as for Tool Steel).

Lead melts at 327°C. but a mixture of lead and tin or lead and antimony (cheaper than tin) melts at lower temperatures as follows:—

Per cent tin	10	20	30	40	50	60
Fluid at ...	300°	275°	255°	230°	210°	185°C.

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Annealing.

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Annealing in engineering works is usually in order to soften tools so that they can be machined. The "softest" steel does not always machine the best.

Quick Method.

Reheat to **just below** the hardening point and cool in air. The nearer the critical point, the softer the steel. The danger of this method is that in the attempt to get as near to the critical point as possible this is often exceeded, at any rate in parts of the tool. This method does not partly remedy the effects of previous overheating nor does it make the steel actually as "soft" as the longer method, but it puts it in condition to machine sweetly.

Usual Method.

Reheat slowly to **slightly above** the hardening point and let it cool all night in the furnace with the doors closed.

To prevent decarburisation, pack in a cast iron box or piece of tube with fine charcoal ashes or lime.

As a means of testing the temperature, have a small hole through the box or cap on the tube through which passes a wire which can be pulled out for inspection and replaced.

Case Hardening.

Case hardening on a commercial scale is not a tool room job and hardly comes within the scope of this small book. One requires proper furnaces (with reliable pyrometers) special packing boxes and considerable metallurgical knowledge. Books recommended :—" Brearley on Case Hardening," " Steel and its Heat Treatment," *Bullens.*

Case hardening is slow and costly and requires considerable experience. Unless carried out under the best conditions the results are liable to be irregular and part of the case hardening surface may peel away from the core under work. There is a tendency for many purposes to adopt instead Alloy Steels requiring only quenching and tempering.

If an odd article is required case hardened and this cannot be purchased, it may be machined in the works and sent to your usual steel suppliers for treatment or one of the firms who make a speciality of this kind of work *e.g.*, The Metal Heat Treatment Ltd., 286, Attercliffe Road, Sheffield, etc. **Pieces for case hardening must be made from one of the special grades of steel made for this purpose.**

If owing to the works being situated abroad, it is impossible to avoid doing the case hardening oneself without proper appliances the following hints may be helpful :—

Case Hardening Compound.

While not recommended for use on a commercial scale, in the case of oddments it is perhaps the least trouble to use one of the many brands of so called special case hardening mixtures on the market. If not available, use powdered charcoal made from wood, bones, hoofs, horns, etc., or a mixture of such charcoal.

Boxes and Packing.

The articles must be carefully and tightly packed in a piece of old tube, cast iron water pipe or metal box and the ends or lid closed with clay so as to be air-tight.

The article must never touch the sides of the box and should be separated from it everywhere by 1" to 2" of compound. The box should as far as possible follow the outline of the piece to be case hardened and not be larger than necessary, as it is difficult to get the heat to penetrate to the centre.

A hole should be left in the end of the box through which a small rod is inserted which can be withdrawn and examined as a guide of the actual temperature of the interior.

Heat Treatment for Carbon Steels.

Carburize at 900/950°C. (1800°F.) and cool in air or quench in oil or water. Reheat to 870°C. (1600°F.) and quench in oil or water.

Reheat to 750°C. (1382°F.) and quench in water.

The first reheating is for the purpose of refining and toughening the core. The second for refining and hardening the case.

The length of time at which the carburising temperature must be maintained, varies greatly and depends on the depth of penetration required, the temperature, the packing, the compound used, the steel used, etc.

Sometimes for a thin case on a small section one hour is enough; for large sections sometimes as much as 24 hours is needed.

For Alloy Steels different treatments are required which will be supplied by the steel maker.

Cracks.

How to locate operation in which cracks have occurred.

If the cracking has occurred in forging, the inside surfaces of the crack will show some scale. Sometimes the scale is very thin and may not be adhering to all parts of the crack. X-Shaped Cracks showing at the ends of a bar have generally been caused in forging.

If in quenching, the fracture surface will show signs of rust or oil, but will not show any signs of tempering colours or scale. "Half moon" or "thumb nail" cracks have nearly always occurred during hardening.

If in tempering, the fracture will show signs of tempering colour (or if tempered in salt bath, of salt).

If in grinding, the cracks are often numerous and very fine, The fracture will not show scale or tempering colour, but if ground wet may show rust as if it had occurred in water hardening.

Having located where the cracking occurs the next question is, what is the cause ?

Causes of Cracks.

Forging cracks are generally due to too rapid or uneven heating, or forging when too cold. Watch the smith at work and you should be able to spot what is the matter.

Round steel must not be drawn down to a smaller size or a taper without hammering it first to a square. Reduce to approximately the finished size as square

then hammer in the corners and round off, otherwise the bar is liable to open up the centre or crack in hardening.

Hardening cracks are generally due to too rapid or uneven heating, or too high a temperature, not moving about in the quenching bath, unsuitable composition of steel, strains caused by bad forging or machining, or stupidity—such as picking up hot pieces in wet tongs, or hardening steel, intended for oil quenching, in water, etc. Again watch the workman. You should be able to detect too rapid or uneven heating.

Examine cracked samples—the direction and shape of the cracks is often a good clue. If an article, such as a drill, is only hardened for part of its length it is very liable to break at the dividing line between the hardened and unhardened portions, if held still when quenched and not moved about in the quenching medium.

Examine the fractures of broken pieces for signs of overheating (i.e., sugary fractures).

Sharp corners and centre punch marks are always liable to start cracks.

Tempering cracks are usually due to trying to heat too rapidly.

Grinding cracks are due to **heat** produced by too much pressure or too little water. High Speed Steel is frequently cracked by careless grinding.

Other causes of cracks (much less common)—Cold working between the rolls sometimes causes cracks which do not appear until hardening.

A crack which forks irregularly is usually traceable to free cementite or cold working.

Split teeth in saws and other cracks in plates and sheets in which the plate tends to split in two along its main axis are generally due to "pipe." These cracks often do not appear until after hardening.

Never put your finger on the fracture, this causes rust and makes investigation more difficult.

N.B.—It is normal for Hot Saws to show small cracks at the bottom of the gullets after working for some time.

Other Troubles.

Steel that won't harden. This is generally due to decarburisation. Test with a file to see if hard under outer skin. Decarburisation may be due to careless heating in the hardening operation (see p. 18), or enough machining allowance (see p. 40) may not have been made to remove decarburised surface caused in earlier operations (rolling, forging, etc.).

A decarburised tool may sometimes be saved by packing in case hardening compound reheating slowly to hardening temperature and quenching.

Soft Spots may be due to the following causes:—(1) Places where steel has been chilled locally below hardening point by contact with cold tongs. (2) Never having been heated to hardening temperature in some parts. (3) Local decarburisation. (4) Tool having been touching dirty coke containing pyrites.

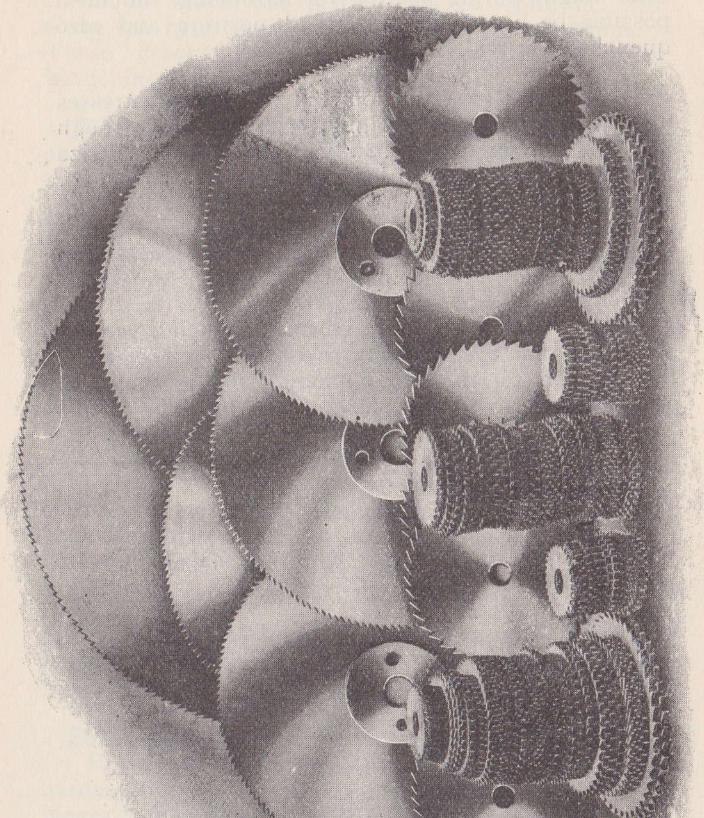
Distortion in hardening is always liable to occur more or less in articles of intricate shape. It is aided by machining stresses and uneven or unskilful heat treatment and quenching.

Long thin articles liable to distort due to their own weight during heating for hardening should if possible be heated in a vertical position and also quenched vertically.

Tools liable to distortion due to internal stresses caused by machining, rolling, etc., should be rough machined down to within about $\frac{1}{16}''$ of finished size and then annealed, finished machined and hardened.

For parts or tools in which distortion is a serious matter, one of the special anti-distortion steels now made (such as "Nonshrinko") should always be used

Steel troubles may often be due to such a variety of causes that the best course is always to refer the the matter to the steel maker, sending them, if possible, *several* samples showing the trouble.



COLD SAWS AND METAL SLITTING SAWS

Spear & Jackson's High-speed Saws are made from "Mermaid" brand High-speed Steel.
Spear & Jackson's Alloy Steel Saws are made from "Spearos" Special Tool Steel.
Many thousands of these Saws are in use in all parts of the world.
Sold on quality—not on price.

PART III.

How to choose the best Steel for Tools

Special Tool Steels.

Just as it is now admitted that it pays to use High Speed-steel for lathe tools etc., in spite of its high cost, so other alloy and special tool steels are gradually replacing ordinary carbon steels for other purposes.

The special property required in lathe tools is the ability to keep a cutting edge when nearly red hot.

Some of the properties aimed at in other special steels are :—

Increased cutting efficiency at ordinary temperatures.

Freedom from distortion in hardening.

Cutting efficiency on extra hard materials.

Resistance to fracture due to fatigue (as in pneumatic snaps and chisels).

Shrinking back to size when rehardened.

Characteristics of S. & J. Special Steels.

High-speed Steels.

Triple Mermaid.
Double Mermaid.
Mermaid.
Leapfrog.

All High-speed Steels used for some purposes and giving results in proportions to their cost price.

Self-hardening Steel.

S. H. 1. A self-hardening tool steel used for similar purposes to High-speed.

S, S. H. A Special self-hardening tool steel; largely used for dies and cutters for nail making machines.

Special Tool Steels.

Finifast. An intensely hard steel. For finishing and for turning very hard substances such as chilled Rolls and Hard Tyres. Gives a smooth finish.

Spearos & Jacksos, for most purposes give nearly equal service. Spearos is for oil hardening, Jacksos for water hardening. Spearos requires rather more care in heat treatment than Jacksos but is preferable where exceptional toughness is required as well as cutting efficiency.

S A J is for cold chisels. Is not difficult to harden correctly.

Easietreat. Easy to harden. Does not require tempering.

Nonshrinko. Does not warp on hardening.

Shrinkos. For dies required to shrink back to original size on hardening.

Special Steels (with Tempering Colours) recommended for High Duty Tools.

In order of choice if we were buying for our own use. In making your selection, however, please bear in mind special characteristics of these steels as given above.

"Spearos" and "Nonshrinko" must be hardened in **OIL.**

BROACHES, Large (say over 1″ square or round).—"Nonshrinko," "Jacksos" (c. 1·15%), "2Z" (c. 1·15%). (High-speed Steel is also sometimes used.) Tempering colour: *Brown.*

BROACHES, Small.—"Nonshrinko," "Spearos" (Hard), "Jacksos" (c. 1·25%), "2Z" (c. 1·25%), (High-speed Steel is also sometimes used.) Tempering Colour: *Brown.*

CAULKING TOOLS (Hand or Pneumatic).—"Spearos" (Very Mild) *Dark Blue to Red,* "S A J" *Dark Blue,* "Jacksos" (c. ·65%) *Blue,* "2Z" (c. ·65%), *Blue.*

Special Steels (with Tempering Colours).—*Continued.*

CHISELS, COLD, Large (say over 1″ oct.),—"S A J" *Good Blue*, "Spearos" (Mild) *Blue*, "Easietreat" *not tempered*, "Jacksos" (c. ·80%) *Blue*, "2Z" (c. ·80%), "N.T."

CHISELS. COLD, Medium (say ¾″ to 1″ oct.).—"S A J" *Good Blue*, "Spearos" (Medium) *Blue*, "Easietreat" *not tempered*, "Jacksos" (c. ·90%) *Blue*, "2Z" (c. ·90%), "N.T." *not tempered.*

CHISELS, COLD, Small (say ½″ to ¾″ oct.).—"Spearos" (Full) *Blue*, "Jacksos" (c. ·95%) *Blue*, "S A J" *Blue*, "Easietreat" *not tempered*, "2Z" (c. ·95%) *Dark Blue*, "N.T," *not tempered.*

CHISELS, PNEUMATIC, Large (say over 1″ oct.).—"Spearos" (Mild) *Dull Red*, "S A J" *Dark Blue*, "Jacksos" (c. ·85%) *Dark Blue*, "Easietreat" *not tempered*, "2Z" (c. ·85%) *Dark Blue.*

CHISELS, PNEUMATIC, Small (say to ¾″ oct.).—"Spearos" (Mild) *Blue*, "S A J" *Dark Blue*, "Jacksos" (c. ·85%) *Dark Blue*, "Easietreat" *not tempered*, "2Z" (c. ·85%) *Dark Blue.*

DIES (Hot Forging and Drop Stamping), Large.—"Spearos" (Mild) *Blue*, "Easietreat" *not tempered*, "Jacksos" (c. ·65%) *Good Blue*, "2Z" (c. ·60%) *Good Blue*, "N.T." *not tempered.*

DIES (Hot Forging and Drop Stamping), Small.—"Spearos" (Hard) *Blue*, "Easietreat" *not tempered*, "Jacksos" (c. ·85%) *Good Blue*, "2Z" (c. ·85%) *Good Blue*, "N.T." *not tempered.* (High-speed Steel is also sometimes used.)

DIES (for Cold Presses), Large.—"Spearos" (Hard) *Light Blue*, "Jacksos" (c. ·85%) *Light Blue*, "2Z" (c. ·85%) *Light Blue.*

DIES (for Cold Presses), Small.—"Spearos" (Hard) *Light Blue*, "Jacksos" (c. ·95%) *Light Blue*, "2Z" (c. ·95%) *Light Blue.* (High-speed Steel is also sometimes used.)

DIES (Screwing),—See Screwing Dies, *Straw.*

DIES (Shrinking),—"Shrinkos" *Straw.*

DRILLS,—"High-speed Steel," "Jacksos" (c. 1·20%), "Nonshrinko" *Straw.*

FLYING-OUT TOOLS (for Hot or Cold Steel), Large.—"Spearos" (Med.), "Jacksos" (c. ·75%), "Easietreat," "2Z" (c. ·75%), Tempering Colour: *Light to Dark Blue.*

FLYING-OUT TOOLS (for Hot or Cold Steel), Small.—"Spearos" (Full), "Jacksos" (c. ·95%), "Easietreat," "2Z" (c. ·95%). (High-speed Steel is sometimes used), *Light to Dark Blue*

FINISHING TOOLS.—"Finifast," "Jacksos" (c. 1·30%), "2Z" (c. 1·30%). (High-speed Steel is also sometimes used.) *Straw.*

Special Steels (with Tempering Colours).—*Continued.*

FORMING TOOLS.—" Finifast," " Jacksos " (c. 1·30%), " Spearos " (V. Hard), " 2Z " (c. 1·30%). (High-speed Steel is also sometimes used.) *Straw.*

FULLERS, BLACKSMITH'S.—" S A J " *Blue*, " Easitreat," " 2Z " (c. ·65%) *Blue*. " N.T."

GAUGES.—" Nonshrinko," " Jacksos " (c. 1·25%), " C1," " 2Z " (c. 1·25%) *Straw.*

HAMMERS, for Pneumatic Riveters.—" Spearos " (Mild) *Dark Blue to Dull Red*, " S A J " *Dark Blue*, " Jacksos " (c. ·65%) *Dark Blue*, " 2Z " (c. ·65%) *Dark Blue.*

MILLING CUTTERS,—High-speed Steel. " Nonshrinko," for oil hardening. " Jacksos " (c. 1·25%), for water hardening. " Spearos " (V. Hard) for oil hardening, *Straw.*

PUNCHES.—See Flying-Out Tools.

REAMERS.—High-speed Steel. " Jacksos " (c. 1·20%), " Spearos " (V. Hard), " Nonshrinko," " 2Z " (1·20%) *Straw.*

ROLL TURNER'S TOOLS.—" Finifast," "Jacksos" (c. 1·35%), " 2Z " (c. 1·45%). (High-speed Steel is also sometimes used.) *Light Straw.*

SNAPS (Hand and Pneumatic).—" Spearos " (Mild) *Dark Blue to Dull Red*, " S A J " *Very Dark Blue*, " Jacksos " (c. ·65%) *Very Dark Blue*, " 2Z " (c. ·65%) *Very Dark Blue.*

SETS.—" S A J " *Dark Straw*, " Easietreat " *not tempered*, " Jacksos " (c. ·65%) *Dark Straw*, " 2Z " (c. ·65%) *Dark Straw*, " N.T." *not tempered.*

SHEAR BLADES, Large.—" Spearos " (Mild), " Jacksos " (c. ·75%), " S A J," " 2Z " (c. ·75%). *Dark Straw.*

SHEAR BLADES, Small.—" Spearos " (Med.), " Jacksos " (c. ·85%), " S A J," " 2Z " (c. ·85%). (High-speed Steel is also sometimes used.) *Dark Straw*

SCREWING DIES.—" Nonshrinko," " Spearos " (Hard), " Jacksos " (c. 1·15%), " 2Z (c. 1·15%) *Straw.*

TAPS.—" Nonshrinko," " Spearos " (V. Hard), " Jacksos " (c. 1·20%), " 2Z " (c. 1·20%). (High-speed Steel is also sometimes used.) *Straw.*

WOOD-WORKING TOOLS (i.e. Cutters, &c.).—" Jacksos " (c. 1·25%), " 2Z " (c. 1·25%) *Straw.*

The carbon percentages given are approximate and for guidance only, and require modification in some cases according to the shape of tool, *what carbon the Smith has been accustomed to use, and the amount of tempering given.*

PART IV.

General Information, Tables, etc.

Detecting Steels by Grinding Stone Sparks.

Steels containing quite small percentages of tungsten can be distinguished from other steels by holding them against a dry emery stone. Tungsten steels give a blood red coloured spark, other steels one which is much yellower.

To some extent hard steel can also be distinguished from mild steel by the same method the sparks in the former case being much more "fiery."

Lathe Tests.

Formula for reckoning cutting speed (*i.e.*, rate at which bar cut is passing tool point) when revolutions per minute are known.

D = Diameter of bar being cut in inches.
*N = Revolutions per minute,
C = Cutting speed in feet per minute.

(1) Correct and accurate $\frac{D \times 3.1416 \times N}{12} = C.$

(2) Approximate $\frac{D \times N}{4} = C.$

(2) is accurate enough for all practical purposes.

*If you cannot get this from Engineer or Turner put a chalk mark on bar, and with watch in hand count roughly the number of revolutions. (This is quite easy to do up to 100 revolutions per minute, and with practice can be counted approximately up to 250.)

To ascertain volume of Metal removed.

Feed × depth of cut × speed in **inches** per minute = cu. ins. removed per minute.

The volume of metal removed per minute is, of course, the real test of cutting efficiency. You can get the same volume of metal removed per minute by a light cut at a high speed or by a heavy cut at a slow speed; as a rule the tool will cut longer without giving way under the latter conditions.

Allowances for Machining.

As all steel becomes more or less decarburised on the surface in forging, rolling, &c., where the finished article is required to be uniformly hard, it is most important not to skimp the machining allowance. The following is recommended—

Up to 3″ diam. allow $\frac{1}{8}$″ on diameter.
3″ to $4\frac{1}{2}$″ ,, ,, $\frac{3}{16}$″ ,,
$4\frac{1}{2}$ to 6″ ,, ,, $\frac{1}{4}$″ ,,
Above 6″ ,, ,, $\frac{3}{8}$″ ,,

Squares, Flats, etc. in proportion.

Measuring Octagonal and Hexagonal Bars.

The correct way of measuring these is from **flat to flat** (not across the face or from corner to corner).

Sheet Steel Equivalents and Weights.

Stubs W.G.	Part Inch.	Dcml. of an Inch.	m/m.	* Lbs. per Sq. Ft.	Stubs W.G.	Part Inch.	Dcmi. of an Inch	m/m.	* Lbs. per Sq. Ft.
00000	$\frac{1}{2}$	.50	12.70	20.32	9		.148	3.74	6·09
	$\frac{15}{32}$	.4687	11.90	19.05		$\frac{9}{64}$	.140	3.57	5.72
0000		.454	11.53	18.46	10		.134	3.41	5.45
	$\frac{7}{16}$	.4375	11.13	17.78		$\frac{1}{8}$	.125	3.17	5.08
000		.425	10.82	17.28	11		.120	3.02	4.88
	$\frac{13}{32}$	.4062	10.33	16.51	12	$\frac{7}{64}$	.109	2.73	4.44
00		.380	9.66	15.45	13		.095	2.42	3.86
	$\frac{3}{8}$	.375	9.53	15.24		$\frac{3}{32}$	.0937	2.38	3.61
	$\frac{11}{32}$	.3437	8.73	13.97	14		.083	2.08	3.37
0		.340	8.65	13.82		$\frac{5}{64}$	.078	2.00	3.18
	$\frac{5}{16}$	.3125	7.95	12.70	15		.072	1.80	2.93
1		.300	7.62	12.20	16		.065	1.64	2.64
	$\frac{19}{64}$	.296	7.54	12.07		$\frac{1}{16}$	.0625	1.58	2.54
2		.284	7.18	11.55	17		.058	1.46	2.36
	$\frac{9}{32}$	.281	7.15	11.43	18		.049	1.23	1.99
	$\frac{17}{64}$	.265	6.74	10.80		$\frac{3}{64}$	.046	1.19	1.91
3		.259	6.57	10.53	19		.042	1.06	1.71
	$\frac{1}{4}$	.250	6.35	10.16	20		.035	.88	1.42
4		.238	6.03	9.68	21		.032	.80	1.30
	$\frac{15}{64}$	.234	5.95	9.53		$\frac{1}{32}$	.0313	.79	1.27
5		.220	5.58	8.95	22		.028	.70	1.14
	$\frac{7}{32}$	.2187	5.55	8.89	23		.025	.62	1.02
6	$\frac{13}{64}$	.203	5.15	8.26	24		.022	.54	.90
	$\frac{3}{16}$	.1875	4.77	7.62	25		.020	.51	.81
7		.180	4.56	7.32	26		.018	.46	.73
	$\frac{11}{64}$	.171	4.36	6.99	27		.016	.41	.65
8		.165	4.18	6.71		$\frac{1}{64}$	.0156	.39	.64
	$\frac{5}{32}$	.1562	3.96	6.35	28		.014	.34	.57

* For High-speed Steels add 10%.

Flat Steel Bars. Lbs. per Foot.

(High Speed add 10%.)

	½	⅝	¾	⅞	1	1⅛	1¼	1⅜	1½	1¾	2	2¼	2½	2¾	3	3½	4	5	6	7
⅛	·213	·266	·320	·372	·426	·479	·530	·585	·640	·745	·850	·955	1·07	1·18	1·28	1·49	1·70	2·13	2·56	2·98
3/16	·319	·339	·480	·558	·639	·718	·790	·878	·960	1·12	1·28	1·43	1·60	1·76	1·92	2·24	2·55	3·20	3·83	4·47
1¼	·425	·533	·640	·743	·852	·958	1·06	1·17	1·28	1·49	1·70	1·91	2·13	2·34	2·56	2·98	3·40	4·26	5·11	5·96
5/16	·531	·665	·800	·929	1·06	1·20	1·33	1·46	1·60	1·86	2·13	2·39	2·66	2.92	3·19	3·72	4·25	5·32	6·38	7·44
⅜	·638	·798	·960	1·12	1·28	1·43	1·59	1·75	1·91	2·23	2·55	2·87	3·20	3·51	3·83	4·46	5·10	6·40	7·66	8·92
7/16	·744	·931	1·12	1·30	1·49	1·67	1·86	2·05	2·23	2·60	2·98	3·35	3·72	4·09	4·46	5·21	5·95	7·44	8·92	10·40
½		1·07	1·28	1·49	1·70	1·91	2·13	2·34	2·55	2·98	3·40	3·83	4·26	4·68	5·10	5·96	6·80	8·52	10·20	11·90
9/16		1·20	1·44	1·67	1·91	2·15	2·39	2·63	2·87	5·35	3·83	4.30	4·78	5·26	5·74	6·69	7·65	9·56	11·50	13·40
⅝			1·60	1·86	2·12	2·39	2·66	2·92	3·19	3·72	4·26	4·79	5·32	5·86	6·39	7·44	8·52	10·64	12·78	14·90
11/16			1·76	2·04	2.34	2·63	2·92	3·22	3·51	4·09	4·68	5·26	5·84	6·43	7·01	8·18	9·35	11.70	14·00	16·40
¾				2·23	2·55	2·86	3·19	3·50	3·83	4·46	5·10	5·74	6·40	7·02	7·65	8·92	10.20	12·80	15·30	17·90
13/16				2·41	2·76	3·11	3·45	3·80	4·14	4·83	5·53	6·22	6.91	7·60	8·29	9·67	11·10	13·80	16·60	19.30
⅞					2·98	3·34	3·72	4·09	4·46	5·21	5·96	6·70	7·46	8·19	8·94	10·42	11·92	14·92	17·88	20·80
15/16					3·19	3·59	3·98	4·38	4·78	5·58	6·38	7·17	7·97	8·77	9·56	11·20	12·80	15·90	19·10	22·40
1						3·82	4·25	4·68	5·10	5·96	6·80	7·66	8·52	9·36	10·20	11·92	13·60	17·04	20·40	23·80
1⅛							4·78	5·27	5·74	6·71	7·65	8·61	9·59	10·54	11·48	13·41	15·30	19·17	22·95	26·80
1¼								5·85	6·38	7·45	8·50	9·57	10·65	11.71	12·76	14·90	17·00	21·30	25·61	29·76
1½								7·02	7·67	8·94	10·20	11·49	12·78	14·04	15·30	17·88	20·40	25·56	30·60	35·70

Weights of Bar Steel.

Lbs. per Foot. High-Speed Steel add 10%.

Size	Round	Square	Size	Round	Square	Size	Round	Square
$\frac{1}{8}$	·04	·05	$1\frac{1}{2}$	6·01	7·65	$3\frac{3}{4}$	37·54	47·80
$\frac{3}{16}$	·09	·12	$1\frac{5}{8}$	7·05	8·98	4	42·72	54·40
$\frac{1}{4}$	·17	·21	$1\frac{3}{4}$	8·18	10·40	$4\frac{1}{4}$	48·30	61·40
$\frac{5}{16}$	·26	·33	$1\frac{7}{8}$	9·38	11·90	$4\frac{1}{2}$	54·60	68·90
$\frac{3}{8}$	·38	·48	2	10·71	13·60	$4\frac{3}{4}$	60·30	76·70
$\frac{7}{16}$	·51	·65	$2\frac{1}{8}$	12·05	15·40	5	66·80	85·00
$\frac{1}{2}$	·67	·85	$2\frac{1}{4}$	13·60	17·20	$5\frac{1}{4}$	73·60	93·70
$\frac{9}{16}$	·85	1·08	$2\frac{3}{8}$	15·10	19·20	$5\frac{1}{2}$	80·80	102·80
$\frac{5}{8}$	1·04	1·33	$2\frac{1}{2}$	16·68	21·20	$5\frac{3}{4}$	88·30	112·40
$\frac{11}{16}$	1·27	1·61	$2\frac{5}{8}$	18·39	23·50	6	96·10	122·40
$\frac{3}{4}$	1·50	1·92	$2\frac{3}{4}$	20·18	25·70	$6\frac{1}{2}$	113·20	143·60
$\frac{13}{16}$	1·76	2·24	$2\frac{7}{8}$	22·06	28·20	7	130·80	166·40
$\frac{7}{8}$	2·04	2·60	3	24·10	30·60	8	170·88	217·60
$\frac{15}{16}$	2·35	3·06	$3\frac{1}{8}$	26·12	33·13	9	218·40	275·60
1	2·67	3·40	$3\frac{1}{4}$	28·30	35·90	10	267·20	340·00
$1\frac{1}{8}$	3·38	4·30	$3\frac{3}{8}$	30·45	38·64	11	323·00	411·20
$1\frac{1}{4}$	4·17	35·1	$3\frac{1}{2}$	32·70	41·60	12	384·40	489·60
$1\frac{3}{8}$	5·05	6·43	$3\frac{5}{8}$	35·20	44·57			

Brinnell Nos. and Tensile Tests. Approximate Equivalents.

Dia. of Ball Impression.	Brinnell Number.	Tons per square inch.	1000 lbs. per sq. in.	Kilos per sq. m/m.	Dia. of Ball Impression.	Brinnell Number.	Tons per square inch.	1000 lbs. per sq. in.	Kilos per sq. m/m.
2·50	601	132	295	208	3·70	269	59	132	93
2·55	578	127	284	200	3·75	262	58	129	91
2 60	555	122	273	192	3·80	255	56	125	89
2·65	534	117	262	179	3·85	248	55	123	87
2·70	514	112	250	176	3 90	241	53	118	84
2·75	495	108	241	170	3·95	235	51	114	81
2·80	477	105	235	165	4·00	229	50	112	79
2·85	461	101	226	160	4·05	223	49	109	77
2·90	444	98	219	155	4·10	217	48	107	76
2·95	429	95	212	150	4·15	212	46	103	73
3·00	415	92	206	145	4·20	207	45	100	71
3·05	401	88	197	139	4·30	197	43	96	68
3 10	388	85	190	134	4·40	187	41	91	65
3·15	375	82	183	130	4·50	179	39	87	62
3·20	363	80	179	126	4·60	170	36	80	57
3·25	352	77	172	122	4·70	163	35	78	55
3·30	341	75	168	118	4·80	156	34	76	54
3·35	331	73	163	114	4·90	149	32	71	51
3·40	321	71	159	111	5·00	143	31	69	49
3·45	311	68	152	107	5·20	131	30	67	47
3·50	302	66	147	104	5·30	126	29	64	46
3·55	293	64	143	101	5·40	121	28	62	44
3·60	285	63	141	99	5·50	116	27	60	43
3·65	277	61	136	96	5·60	111	25	56	40

Temperature Conversion Table.

Deg C	0	10	20	30	40	50	60	70	80	90
	F	F	F	F	F	F	F	F	F	F
0	32	50	68	86	104	122	140	158	176	194
100	212	230	248	266	284	302	320	338	356	374
200	392	410	428	446	464	482	500	518	536	554
300	572	590	608	626	644	662	680	698	716	734
400	752	770	788	806	824	842	860	878	896	914
500	932	950	968	986	1004	1022	1040	1058	1076	1094
600	1112	1130	1148	1166	1184	1202	1220	1238	1256	1274
700	1292	1310	1328	1346	1264	1382	1400	1418	1436	1454
800	1472	1490	1508	1526	1544	1562	1580	1598	1616	1634
900	1652	1670	1688	1706	1724	1742	1760	1778	1796	1814
1000	1832	1850	1868	1886	1904	1922	1940	1958	1976	1994
1100	2012	2030	2048	2066	2084	2102	2120	2138	2156	2174
1200	2192	2210	2228	2246	2264	2282	2300	2308	2336	2354
1300	2372	2390	2408	2426	2444	2462	2480	2498	2516	2534

C	F
1	1·8
2	3·6
3	5·4
4	7·2
5	9·0
6	10.8
7	12·6
8	14·4
9	16·2

Deg F	0	10	20	30	40	50	60	70	80	90
	C	C	C	C	C	C	C	C	C	C
0	—17·8	—12·2	—6·7	—1·1	4.4	10·0	15·6	21·1	26·7	32·2
100	37·8	43.3	48·9	54·4	60·0	65·6	71·1	76.7	82·2	87·8
200	93·3	98.9	104·4	110·0	115·6	121·1	126·7	132·2	137·8	143·3
300	148·9	154·4	160·0	165·6	171·1	176·7	182·2	187·8	193·3	198·9
400	204·4	210·0	215·6	221·1	226.7	232·2	237·8	243·3	248·9	254·4
500	260·0	265.6	271·1	276·7	282·2	287·8	293·3	298·9	304·4	310·0
600	315·6	321·1	326·7	332·2	337·8	343·3	348·9	354·4	360·0	365·6
700	371·0	376·7	382·2	387·8	393·3	398·9	404·4	410·0	415·6	421·1
800	426·7	432·2	438·7	443·3	448·9	454·4	460·0	465·6	471·1	476·7
900	482·2	487·8	493.3	498·9	504·4	510·0	515.6	521·1	526·7	532·2
1000	537·8	543·3	548·9	554·4	560·0	565·6	571·1	576·7	582·2	587·8
1100	593·3	598·9	604·4	610·0	615·6	621·1	626·7	632·2	637·8	643·3
1200	648·9	654·4	660·0	665·6	671·1	676·7	682·2	687·8	693·3	698·9
1300	704·4	710·0	715·6	721·1	726·7	732·2	737·8	743·3	748·9	754·4
1400	760·0	765·6	771·1	776·7	782·2	787·8	793·3	798·9	804·4	810·0
1500	815·0	821·1	826·7	832·2	837·8	843·3	848·9	854·4	860·0	865·6
1600	871·1	876.7	882·2	887·8	893·3	898·9	904·4	910·0	915.6	921·1
1700	926·7	932 2	937·8	943·3	948·9	954·4	960·0	965·6	971·1	976·7
1800	982·2	987·8	993·3	998·9	1004·4	1010·0	1015·6	1021·1	1026·7	1032·2
1900	1037·8	1043·3	1048·9	1054·4	1060·0	1065·6	1071·1	1076·7	1082·2	1087·8
2000	1093·3	1098·9	1104·4	1110·0	1115·6	1121·1	1126·7	1132·2	1137·8	1143·3
2100	1148·9	1154·4	1160·0	1165·6	1171·1	1176·7	1182·2	1187·8	1193·3	1198·9
2200	1204·4	1210·0	1215·6	1221·1	1226·7	1232·2	1237·8	1243·3	1248·9	1254·4
2300	1260·0	1265·6	1271·1	1276·7	1282·2	1287·8	1293.3	1298·9	1304·4	1310·0
2400	1315·6	1321·1	1326·7	1332·2	1337·8	1343·3	1348·9	1354·4	1360·0	1365·6

F	C
1	·6
2	1·1
3	1·7
4	2.2
5	2·8
6	3·3
7	3·9
8	4·5
9	5·0

Tenths of m/m compared with Stubbs' Wire Gauge.

10ths of m/m		No. W.G.	10ths of m/m		No. W.G.
1	equals	36	25	equals	12 V.E.
2	,,	33	26	,,	12 E.
3	,,	29	27	,,	12
4	,,	27	28	,,	12 T.
4	,,	24 E.	29	,,	11 E.
6	,,	23	30	,,	11 T.
7	,,	22	31	,,	10 V.E.
8	,,	21	32	,,	10 E.
9	,,	20 T.	33	,,	10
10	,,	19 E.	34	,,	10 T.
11	,,	19 V.T.	35	,,	9 V.E.
12	,,	18 E.	36	,,	9
13	,,	18 T.	37	,,	9 T.
14	,,	17	38	,,	8 V.E.
15	,,	16 E.	39	,,	8 E.
16	,,	16 V.T.	40	,,	8
17	,,	15 E.	45	,,	7
18	,,	15 V.T.	50	,,	6
19	,,	14 V.E.	55	,,	5
20	,,	14 E.	60	,,	4
21	,,	14 T.	65	,,	3
22	,,	13 V.E.	70	,,	2
23	,,	13	75	,,	1
24	,,	13 T.			

Stubbs' Wire Gauge and parts of an Inch.

Gauge	Decimal Equiv.		Nearest Fraction of an Inch	Gauge	Decimal Equiv.		Nearest Fraction of an Inch
No. 1	·300	equals	$\frac{5}{16}''$ bare	No. 12	·110	equals	$\frac{7}{64}''$
,, 2	·284	,,	$\frac{9}{32}''$ full	,, 13	·096	,,	$\frac{3}{32}''$
,, 3	·256	,,	$\frac{1}{4}''$ full	,, 14	·086	,,	$\frac{5}{64}''$ full
,, 4	·240	,,	$\frac{1}{4}''$ bare	,, 15	·072	,,	$\frac{5}{64}''$ bare
,, 5	·220	,,	$\frac{7}{32}''$	,, 16	·064	,,	$\frac{1}{16}''$ full
,, 6	·203	,,	$\frac{13}{64}''$	,, 17	·058	,,	$\frac{1}{16}''$ bare
,, 7	·180	,,	$\frac{3}{16}''$ bare	,, 18	·048	,,	$\frac{3}{64}''$ full
,, 8	·167	,,	$\frac{11}{64}''$	,, 19	·040	,,	$\frac{3}{64}''$
,, 9	·148	,,	$\frac{5}{32}''$ bare	,, 20	·036	,,	
,, 10	·136	,,	$\frac{9}{64}''$	,, 21	·032	,,	$\frac{1}{32}''$ full
,, 11	·121	,,	$\frac{1}{8}''$ bare	,, 22	·034	,,	$\frac{1}{32}''$ bare

Table of Decimal Equivalents of Fractions of an Inch.

$\frac{1}{64}$	equals	·015625	$\frac{33}{64}$	equals	·515625
$\frac{1}{32}$	,,	·03125	$\frac{17}{32}$	,,	·53125
$\frac{3}{64}$	,,	·046875	$\frac{35}{64}$	,,	·546875
$\frac{1}{16}$	,,	·0625	$\frac{9}{16}$	,,	·5625
$\frac{5}{64}$	,,	·078125	$\frac{37}{64}$	,,	·578125
$\frac{3}{32}$	,,	·09375	$\frac{19}{32}$	,,	·59375
$\frac{7}{64}$	,,	·109375	$\frac{39}{64}$	,,	·609375
$\frac{1}{8}$	,,	·125	$\frac{5}{8}$	,,	·625
$\frac{9}{64}$	,,	·140625	$\frac{41}{64}$	,,	·640625
$\frac{5}{32}$	,,	·15625	$\frac{21}{32}$	,,	·65625
$\frac{11}{64}$	,,	·171875	$\frac{43}{64}$	,,	·671875
$\frac{3}{16}$	,,	·1875	$\frac{11}{16}$	,,	·6875
$\frac{13}{64}$	,,	·203125	$\frac{46}{64}$	,,	·703125
$\frac{7}{32}$	,,	·21875	$\frac{23}{32}$	,,	·71875
$\frac{15}{64}$	,,	·234375	$\frac{47}{64}$	,,	·734375
$\frac{1}{4}$	,,	·250	$\frac{3}{4}$	,,	·750
$\frac{17}{64}$	,,	·265625	$\frac{49}{64}$	,,	·765625
$\frac{9}{32}$	,,	·28125	$\frac{25}{32}$	,,	·78125
$\frac{19}{64}$	,,	·296875	$\frac{51}{64}$	,,	·796875
$\frac{5}{16}$	,,	·3125	$\frac{13}{16}$	,,	·8125
$\frac{21}{64}$	,,	·328125	$\frac{53}{64}$	,,	·828125
$\frac{11}{32}$	,,	·34375	$\frac{27}{32}$	,,	·84375
$\frac{23}{64}$	,,	·359375	$\frac{55}{64}$	,,	·859375
$\frac{3}{8}$	,,	·375	$\frac{7}{8}$	,,	·875
$\frac{25}{64}$	,,	·390625	$\frac{57}{64}$	,,	·890625
$\frac{13}{32}$	,,	·40625	$\frac{29}{32}$	,,	·90625
$\frac{27}{64}$	,,	·421875	$\frac{59}{64}$	,,	·921875
$\frac{7}{16}$	,,	·4375	$\frac{15}{16}$	,,	·9375
$\frac{29}{64}$	,,	·453125	$\frac{61}{64}$	,,	·953125
$\frac{15}{32}$	,,	·46875	$\frac{31}{32}$	,,	·96875
$\frac{31}{64}$	,,	·484375	$\frac{63}{64}$	,,	·984375
$\frac{1}{2}$	,,	·500			

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